

AMENDMENTS TO THE SPECIFICATION:

On page 1, immediately following the title please insert a heading as follows:

BACKGROUND OF THE INVENTION

On page 1, line 6 please delete the heading.

On page 1, line 6 please insert a heading as follows:

Related Technology

The paragraphs beginning on page 1, line 7 have been changed as follows:

One class of opto-electrical devices is that using an organic material for light emission or detection. The basic structure of these devices is a light emissive organic layer, for instance a film of a poly (p-phenylenevinylene) ("PPV") or polyfluorene, sandwiched between a cathode for injecting negative charge carriers (electrons) and an anode for injecting positive charge carriers (holes) into the organic layer. The electrons and holes combine in the organic layer generating photons. In WO 90/13148 the organic light-emissive material is a polymer. In US 4,539,507 the organic light-emissive material is of the class known as small molecule materials, such as (8-hydroxyquinoline) ~~aluminium~~ aluminum ("Alq3"). In a practical device one of the electrodes is transparent, to allow the photons to escape the device.

A typical organic light-emissive device ("OLED") is fabricated on a glass or plastic substrate coated with a transparent first electrode such as indium-tin-oxide ("ITO"). A layer of a thin film of at least one electroluminescent organic material covers the first electrode. Finally, a cathode covers the layer of electroluminescent organic material. The cathode is typically a metal or alloy and may comprise a single layer, such as ~~aluminium~~ aluminum, or a plurality of layers such as calcium and ~~aluminium~~ aluminum. Other layers can be added to

the device, for example to improve charge injection from the electrodes to the electroluminescent material. For example, a hole injection layer such as poly(ethylene dioxythiophene) / polystyrene sulfonate (PEDOT-PSS) or polyaniline may be provided between the anode and the electroluminescent material. When a voltage is applied between the electrodes from a power supply one of the electrodes acts as a cathode and the other as an anode.

The paragraph beginning on page 2, line 24 has been changed as follows:

One approach that ~~utilises~~ utilizes charge transporting materials for solution processable systems without requiring formation of multiple layers is disclosed in WO 99/48160 and WO 02/28983 wherein a hole transporting component, an electron transporting component and an emissive component are blended together.

The sentence on page 3, line 8 has been changed as follows:

wherein $w + x + y = 1$, $w < 0.5$, $0 \leq x + y \leq 0.5$ and $n < 2$

The paragraph beginning on page 4, line 3 has been changed as follows:

Co-pending international application ~~PCT-GB03/01991~~ PCT/GB03/01991 describes improvement in the lifetime of polymer (a) by removal of the hole transporting “TFB” repeat unit to provide a polymer wherein both hole transport and emission is provided by the “PFB” repeat unit.

On page 4, after line 11 please insert a heading as follows:

GENERAL DESCRIPTION OF THE INVENTION

The paragraphs beginning on page 4, line 12 have been changed as follows:

~~It is therefore an object of the present~~ The invention to provide provides an electroluminescent device, in particular an electroluminescent device comprising a blue emitter, having improved lifetime.

~~Summary of the Invention~~

~~The present inventors have~~ It has been surprisingly found that deposition of a blend comprising a hole transporting material and an electroluminescent material containing a hole transporting unit provides improved lifetime.

The paragraph beginning on page 4, line 21 has been changed as follows:

providing a substrate comprising a first electrode for injection of charge carriers of a first type;

The heading on page 8, line 15 has been changed as follows:

~~Brief Description of the Drawings~~

BRIEF DESCRIPTION OF THE DRAWINGS

The paragraph beginning on page 8, line 16 has been changed as follows:

The ~~present~~ invention will now be described in further detail, by way of example only, with reference to the accompanying drawings in which:

The heading beginning on page 8, line 23 has been changed as follows:

~~Detailed Description of the Invention~~

DETAILED DESCRIPTION OF THE INVENTION

The paragraph beginning on page 8, line 24 has been changed as follows:

With reference to Figure 1, the standard architecture of an optical device according to the invention, in particular an electroluminescent device, comprises a transparent glass or plastic substrate 1, an anode of indium tin oxide 2 and a cathode 4. A semiconducting region is located 3 between the anode 2 and the cathode 4.

~~Semiconducting~~ The semiconducting region 3 may comprise the first and second materials according to the invention alone, or may comprise further materials. The first and second materials are preferably deposited from solution in the form of a blend, which may undergo partial or total phase separation upon evaporation of the solvent. If the first or second materials do not provide one of the functions of hole transport or electron transport, then a further material providing this function may be included in semiconducting region 3 either as a separate material blended with the first and second materials as disclosed in WO 99/48160 or as unit incorporated into the first or second material, in particular a repeat unit of a polymer as disclosed in WO 00/55927. The further material may also be provided as a separate layer within the semiconducting region 3.

The paragraph beginning on page 10, line 16 has been changed as follows:

Two ~~polymerisation~~ polymerization techniques that are particularly amenable to preparation of conjugated polymers from aromatic monomers are Suzuki ~~polymerisation~~ polymerization as disclosed in, for example, WO 00/53656 and Yamamoto ~~polymerisation~~ polymerization as disclosed in, for example, "Macromolecules", 31, 1099-1103 (1998). Suzuki ~~polymerisation~~ polymerization entails the coupling of halide and boron derivative functional groups; Yamamoto ~~polymerisation~~ polymerization entails the coupling of halide functional groups. Accordingly, it is preferred that each monomer is provided with two reactive functional groups P wherein each P is independently selected from the group consisting of (a) boron derivative functional groups selected from boronic acid groups, boronic ester groups and borane groups and (b) halide functional groups.

Although not essential, a layer of organic hole injection material (not shown) between the anode 2 and the semiconducting region polymer layer 3 is desirable because it assists hole injection from the anode into the layer or layers of semiconducting polymer. Examples of organic hole injection materials include poly(ethylene dioxythiophene) (PEDT / PSS) as disclosed in EP 0901176 and EP 0947123, or polyaniline as disclosed in US 5723873 and US 5798170.

~~Cathode~~ The cathode 4 is selected from materials that have a ~~workfunction~~ work function allowing injection of electrons into the electroluminescent layer. Other factors influence the selection of the cathode such as the possibility of the adverse interactions between the cathode and the electroluminescent material. The cathode may consist of a single material such as a layer of ~~aluminium~~ aluminum. Alternatively, it may comprise a plurality of metals, for example a bilayer of calcium and ~~aluminium~~ aluminum as disclosed in WO 98/10621, elemental barium disclosed in WO 98/57381, Appl. Phys. Lett. 2002, 81(4), 634 and WO 02/84759 or a thin layer of dielectric material to assist electron injection, for example lithium fluoride disclosed in WO 00/48258 or barium fluoride, disclosed in Appl. Phys. Lett. 2001, 79(5), 2001.

Electroluminescent displays according to the invention may be monochrome displays or full ~~colour~~ color displays (i.e. formed from red, green and blue electroluminescent materials). An electroluminescent device according to the invention may also be used for lighting, in particular as a source of white light. For example, the device may comprise a blue electroluminescent polymer with means for downconverting a portion of the blue polymer by means of red and green downconverters in order to produce white light from a blend of red, green and blue emission as disclosed in, for example, US 6515314 wherein downconversion is provided by nanoparticles located within the layer of emissive material or Applied Physics Letters 80(19), 3470-3472, 2002 wherein downconverter particles are attached to the outer surface of the substrate of the device.

Examples

EXAMPLE

The paragraph beginning on page 14, line 11 has been changed as follows:

4,4-dibromo-2-methyl ester-biphenyl (24.114g, 65.1 mmol) was dissolved in dry diethyl ether (120 mL) and the solution was cooled to -60 °C by using an isopropanol/dry ice bath. Phenyl lithium (1.8M solution in cyclohexane-ether, 91 mL) was then added dropwise. The mixture was stirred and let to warm to room temperature. The reaction was complete after four hours. Water was added (70 mL) then the aqueous layer washed once with diethyl ether. Combined organic phases were washed with sodium chloride, dried over magnesium sulfate, filtered and evaporated to give a yellow powder. ~~Recrystallisation~~ Recrystallization from isopropanol afforded 19g of white solid (59% yield); GC-MS (m/z, relative intensity %) 494 (M^+ , 100); 1H NMR ($CDCl_3$) 7.43 (1H, dd, J 8.4, 2.4), 7.28 (6H, m), 7.23 (2H, d, J 8.0), 7.11 (4H, m), 6.99 (1H, d, J 2.4), 6.94 (1H, d, J 8.4), 6.61 (2H, d, J 8.4) ; ^{13}C NMR ($CDCl_3$) 147.5, 146.7, 140.3, 139.3, 134.0, 133.0, 131.2, 131.1, 130.3, 128.2, 128.1, 127.8, 121.8, 121.3, 83.2.

The paragraph beginning on page 17, line 3 has been changed as follows:

Onto indium tin oxide supported on a glass substrate (available from Applied Films, Colorado, USA) was deposited a layer of PEDT / PSS, available from Bayer ® as Baytron P ® by spin coating. A solution of a blend of TFB and polymer P1 were deposited over the PEDT / PSS layer by spin-coating. Onto the polymer P1 was deposited by evaporation a cathode consisting of a first layer of barium and a second, capping layer of ~~aluminium~~ aluminum.

The paragraph beginning on page 17, line 15 has been changed as follows:

As can be seen from the results, lifetime of devices comprising a blend according to the invention show around a four- to five-fold increase in lifetime. The effect of using a different solvent on lifetime indicates that phase separation effects in the blend play a role in determining device performance. The improvement in lifetime of P1 by blending with F8-TFB copolymer is surprising given that removal of TFB units from polymer (a) described above was previously found to improve lifetime, and given that unblended polymers have previously been found to afford superior lifetimes as compared to blended polymers. Without wishing to be bound by any theory, it is believed that the blend according to the invention undergoes vertical phase separation such that F8-TFB copolymer migrates towards the anode side of the device which would, in effect, result in formation of a hole transporting layer of F8-TFB located between the anode and the electroluminescent layer which would also act to serve as a barrier against ingress of impurities from ITO and / or PEDOT into the electroluminescent material. Deposition of a hole transporting layer followed by an electroluminescent layer is well known in the art, however the ~~present~~ invention enables formation of a hole transporting layer and an electroluminescent layer in a one-step process. Furthermore, the ~~present~~ invention takes advantage of phase-separation effects in order to, in effect, form a multilayer device thus overcoming the aforementioned difficulty in forming multilayers of solution processable materials.

The paragraphs beginning on page 23, line 7 have been changed as follows:

By washing away the upper portion of the blended layer, the composition of the few ~~nanometres~~ nano meters close to the anode can be probed spectroscopically. This technique has confirmed that vertical phase separation occurs in the blends with the hole transporter (e.g. TFB) preferentially moving to the anode. The molecular weight of the hole transporter is critical for this process, with high molecular weight samples showing no sign of hole transporter migration to the anode.

Although the ~~present~~ invention has been described in terms of specific exemplary embodiments, it will be appreciated that various modifications, alterations and / or combinations of features disclosed herein will be apparent to those skilled in the art without departing from the spirit and scope of the invention as set forth in the following claims.